Steel

Steel Annual Report
Fiscal Year 2003

Industrial Technologies Program
Boosting the productivity and competitiveness of U.S. industry
through imporvements in energy and environmental performance

U.S. Department of Energy
Energy Efficiency and Renewable Energy

Industrial Technologies Program — Boosting the Productivity and Competitiveness of U.S. Industry

Industry consumes 33 percent of all energy used in the United States. By developing and adopting more energy efficiency technologies, U.S. industry can boost its productivity and competitiveness while strengthening national energy security, improving the environment, and reducing emissions linked to global climate change.

The U.S. Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy (EERE) works in partnership with U.S. industry to increase the efficiency of energy and materials use, both now and in the future. Through an innovative strategy known as Industries of the Future (IOF), EERE's Industrial Technologies Program (ITP) seeks to improve the energy intensity of the U.S. industrial sector through a coordinated program of research and development (R&D), validation, and dissemination of energy efficiency technologies and operating practices. ITP develops, manages, and implements a balanced portfolio that addresses industry requirements throughout the technology development cycle. The primary long-term strategy is to invest in high-risk, high-return R&D. Investments are focused on technologies and practices that provide clear public benefit but for which market barriers prevent adequate private-sector investment.

The IOF strategy maximizes the energy and environmental benefits of ITP's process-specific technology investments by forming collaborative partnerships with energy-intensive industries. These collaborations aim to effectively plan and implement comprehensive R&D agendas and help disseminate and share best energy management practices throughout the United States. The IOF public-private partnerships also facilitate voluntary efforts, such as the President's Climate VISION initiative, to encourage industry and government to reduce greenhouse gas emissions. ITP focuses its resources on a small number of energy-intensive materials and process industries that account for over 75 percent of industrial energy consumption:

- Aluminum
- Chemicals
- Forest Products
- Glass
- Metal Casting
- Mining
- Petroleum Refining
- Steel

ITP also conducts R&D projects on enabling technologies that are common to many industrial processes such as industrial energy systems, combustion, materials, and sensors and process control systems. In addition, ITP funds technical assistance activities to stimulate near-term adoption of best energy-saving technologies and practices within industry. These activities include plant assessments, tool development and training, information dissemination, and showcase demonstrations.

New technologies that use energy efficiently also lower emissions and improve productivity. By leveraging technical and financial resources of industry and government, the IOF partnerships have generated significant energy and environmental improvements that benefit the nation and America's businesses. Energy-intensive industries face enormous competitive pressures that make it difficult to make the necessary R&D investments in technology to ensure future efficiency gains. Without a sustained commitment by the private and public sectors to invest in new technology R&D and deployment, the ability to close the gap between U.S. energy supply and demand will be severely compromised.

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EXECUTIVE SUMMARY

Steel is one of the most energy-intensive industries in the United States. The steel industry is critical to the U.S. economy, providing the backbone of construction, transportation, and manufacturing as well as being the material of choice for a variety of consumer products. Traditionally valued for its strength, steel has also become one of the most recycled materials, with two-thirds of U.S. steel now produced from scrap.

Since the late 1990s, the U.S. steel industry has been hurt by large quantities of low-cost imports stemming from excess global steelmaking capacity and a collapse in Asian demand. This crisis has exacerbated the industry's existing problem of low profits and relatively low investment in research and development. Permanent technology changes, rather than short-term fixes, are needed to revolutionize the way energy is used in the manufacturing of iron and steel. Unfortunately, the industry is unable to support high-risk, long-term research on revolutionary technologies that could change the way steel is made and greatly reduce its energy requirements.

Public-private research partnerships, such as those fostered by the U.S. Department of Energy (DOE), Office of Energy Efficiency and Renewable Energy (EERE), Industrial Technologies Program (ITP), are critical to maintaining the global competitive position of the U.S. steel industry. Studies sponsored by EERE have quantified the opportunity for saving energy in steelmaking (defined as the difference between today's energy use and the practical minimum energy use). The DOE goal in this area is: by 2020 to develop technologies that will capture half of this opportunity – equivalent to an 18 percent decrease in energy intensity over values projected for 2010.

A Successful Partnership with Industry

DOE's Office of Energy Efficiency and Renewable Energy leads federal development of advanced energy-efficient and environmentally friendly industrial technologies. Steel industry R&D is a component of the overall EERE strategy and contributes to reducing the energy intensity of industry, a goal outlined in the National Energy Policy.

EERE/ITP's Industries of the Future (IOF) strategy was designed to foster industry-government partnerships in economically imperative, energy-intensive U.S. industries such as steel. This strategy has created the impetus for industry to develop long-term visions and roadmaps. Visions establish long-term goals for the future, while roadmaps outline the R&D pathways for achieving the goals. The *Steel Industry Technology Roadmap*, published in 1998 and revised in 2002, has provided the basis for solicitations of pre-competitive R&D that addresses both energy efficiency goals outlined in the National Energy Policy and steel industry research priorities. This successful industry-government partnership has now evolved to a point where it is focusing on potentially high-impact research to make revolutionary improvements in ironmaking and steelmaking.

Steel Goal for 2020: *Reduce the energy intensity of both ore-based and EAF steelmaking by 18 percent over projected values for 2010*

Strong industry involvement ensures direct application of research results and testifies to the importance of this cost-shared research partnership. A major collaborator in this partnership is the American Iron and Steel Institute (AISI), which manages projects that address key priorities defined by the industry under the Technology Roadmap Program (TRP). Involving industry in the early R&D stages helps accelerate the development and application of energy-efficiency technologies. The partnership also emphasizes university and national laboratory-based research in order to tap into the technical resources of our nation's educational institutions and national laboratory systems.

Achieving Energy Savings: Portfolio Strategy

The Steel portfolio supports cost-shared, pre-competitive research addressing technological needs that have broad application throughout the steel industry. ITP has devised a strategy to foster both revolutionary ironmaking and steelmaking technologies and incremental improvements to existing processes, thereby addressing long-term goals, as well as short-term needs. ITP also strives to expand the industry's fundamental base of knowledge to optimize key processes and resource efficiency.

The Department of Energy Program recently conducted an energy bandwidth analysis that compared the practical minimum energy intensity of major steelmaking processes with energy intensity typical of today's processes. The results of this analysis are helping DOE identify the best opportunities for future R&D thrusts. As a result, DOE is now targeting high-risk, potentially high-impact opportunities for reducing the energy intensity of steel industry processes.

To facilitate this shift toward higher-impact projects, the Steel portfolio is organized into four categories: Next Generation Steelmaking, Cokeless Ironmaking, Advanced Process Development, and Power Delivery Modeling. The Cokeless Ironmaking and Next Generation Steelmaking categories include several revolutionary technologies selected by DOE for development under its recent Ironmaking and Steelmaking Challenge solicitations. Power Delivery Modeling represents an exciting new area of opportunity, one that has a potentially widespread impact across the industrial sector.

FY 2003 Highlights

- The pilot demonstration plant for the *Mesabi Nugget Ironmaking* project, part of an exciting, large-scale initiative to demonstrate the revolutionary ITmk3 ironmaking process, has completed its first 30 days of continuous operation.

- A *hot-strip mill model* that simulates hot-strip mill operations and predicts the steel's final mechanical properties has been released by the Integ Process Group, Inc.

- A *laser-based ultrasonic tube wall thickness gauge* installed at the Timken Company's #4 mill has checked the quality of nearly 400,000 tubes produced at the mill as of June 2003. The reduction in out-of-spec product has led to savings of more than 20 billion Btus, worth over half a million dollars.

- Two projects exploring innovative new ways to produce steel continued in 2003. *Novel direct steelmaking by combining microwave, electric arc, and exothermal heating technologies* would eliminate the ironmaking step, while *future steelmaking processes* would develop a flexible fossil fuel-based process as an alternative to coke-based blast furnace ironmaking.

- Major progress has been made in developing materials to increase the *pot hardware life on steel galvanizing lines* by a factor of ten.

- Tamco Steel was the first site of an effort to *improve the efficiency of electric arc furnaces*. Using the Steelmaker Pilot, an intelligent process control system developed under a joint effort with the Steel Manufacturers Association, Tamco is now capable of producing a ton of molten steel using less than 400 kWh.

- The Timken Company is developing process models for c*ontrolled thermo-mechanical processing of tubes and pipes* in collaboration with Oak Ridge National Laboratory, Sandia National Laboratory, and the Colorado School of Mines. Timken expects annual savings of 70 million cubic feet of natural gas in their furnaces from their recent implementation of modeling research results.

- The University of Missouri-Rolla has been awarded a contract for a *continuous process for melting, refining, and casting steel* that will convert preheated steel scrap into high-quality steel.

- Bethlehem Steel began successful operation of a set of 101 *nickel aluminide transfer rolls* in its slab plate mill in Burns Harbor, Indiana. The new rolls have reduced the number of shutdowns related to roll blistering and have improved product quality, leading to significant cost and energy savings.

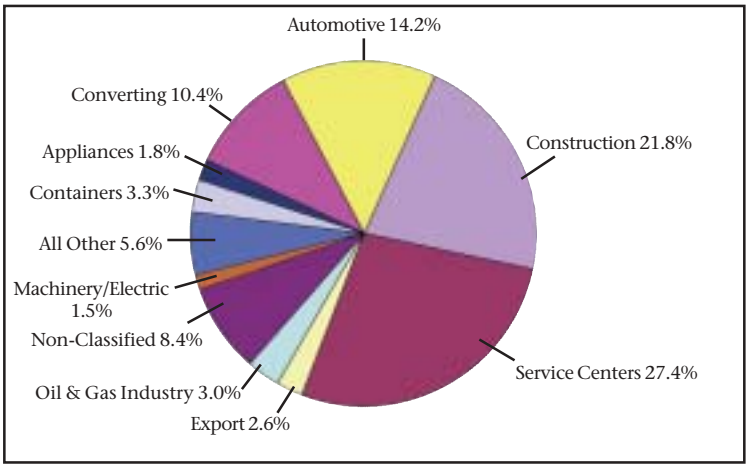
- A new *molten metal flow control system* has been tested that provides the precise control needed for efficient casting. Reduced metal oxidation and impurity entrapment will save 2 trillion Btus per year and improve product quality.

- Two steel companies – Charter Steel of Wilton, Iowa and North Star Steel of Saukville, Wisconsin – completed cost-shared *plant-wide assessments* of their plant utility systems in FY 2003. One new steel company, Fawbrook Steel, was awarded an assessment this year. These assessments can help companies cut energy costs by up to $10 million per year.

INDUSTRY OVERVIEW

Steel is an integral part of the U.S. infrastructure, providing the foundation for construction (bridges, buildings), transportation systems (railroads, cars, trucks), and utility systems (municipal water systems, power systems). It is also the material of choice for such diverse applications as military equipment, food storage, appliances, and tools. Exhibit 1 shows some of steel's largest markets.

Exhibit 1
2001 Steel Shipments by Market Classification



Energy Use in Steelmaking

Steel is made by two different routes, both of which are energy-intensive. An integrated steel mill produces molten iron in blast furnaces using a form of coal known as coke, which is either produced on-site or purchased. This iron is used as a charge to produce steel in a basic oxygen furnace (BOF). An electric arc furnace steel producer, also known as a mini-mill, uses electric arc furnaces (EAFs) to produce steel from steel scrap and other iron-bearing materials.

The steel industry consumed 2 quadrillion Btu in 1998, 0.3 quad of which was supplied from within the plant in the form of byproduct gases (DOE, 2000). As shown in Exhibit 2, nearly 40 percent of the industry's energy consumption is supplied by coal and coke. The byproduct fuels – coke oven gas and blast furnace gas – recovered from cokemaking and ironmaking, respectively, represent another 15 percent of the industry's total energy consumption. Blast furnace ironmaking and electric arc furnace steelmaking are among the most energy-intensive processes in the industry.

In 2000, the industry spent nearly $4.5 billion on purchased fuels and electricity. On average, energy purchases represented about 15 percent of the cost of production in iron and steel manufacturing.

Energy end-use patterns can be illustrated through the use of an energy footprint that identifies both energy use and losses due to equipment and system inefficiencies (Exhibit 3). Within the plant boundary, about a quarter of the energy delivered to the plant is lost prior to being used in specific processes. Process heating (including the blast furnace, steelmaking furnaces, reheat furnaces, other furnaces, and boilers) represents the largest use of fuels in the steel industry (60 percent). Technologies that improve the efficiency of furnaces and other process heating systems have significant potential to reduce overall steel industry energy use.

Exhibit 2
Energy Use in the Steel Industry

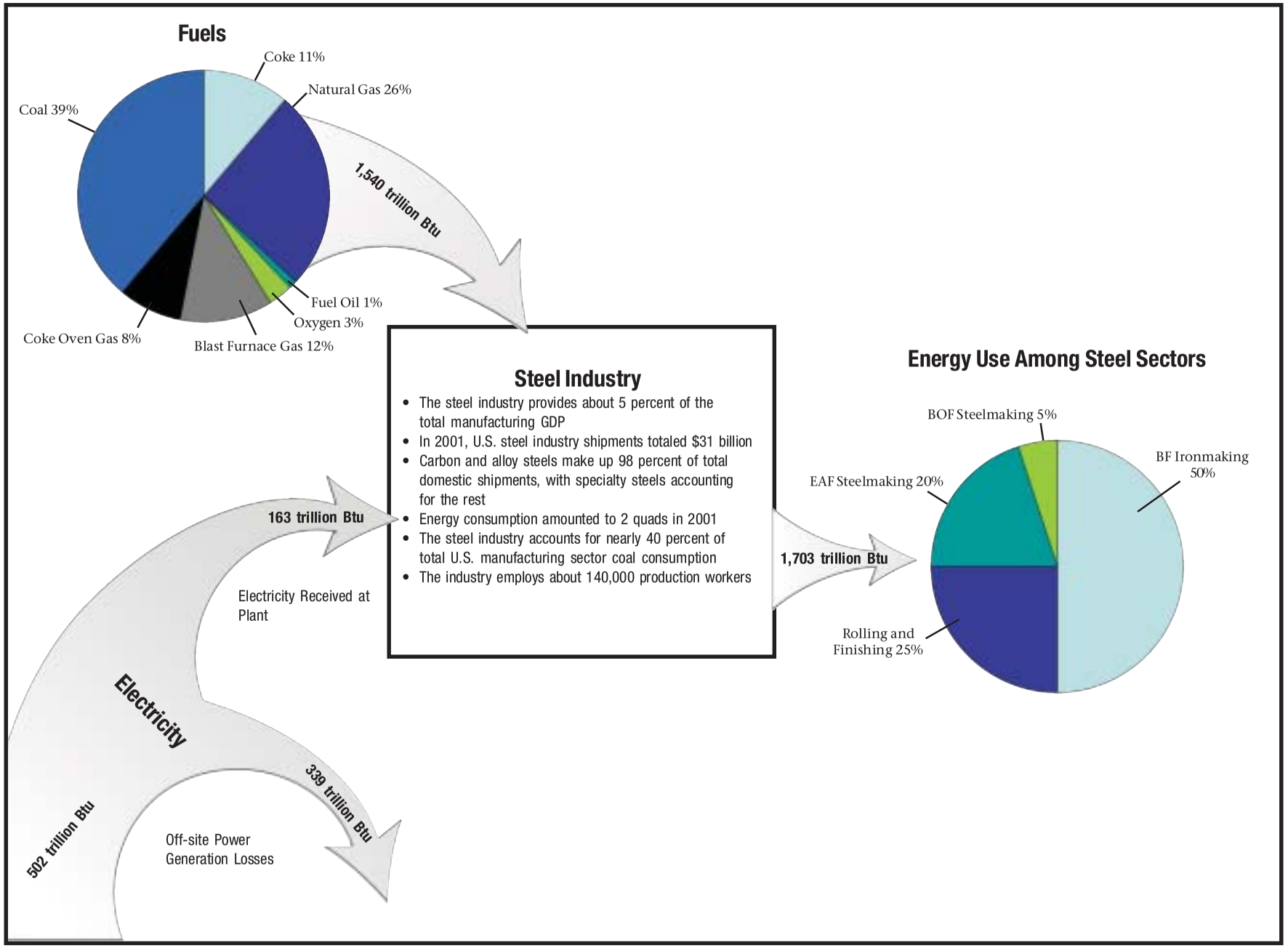
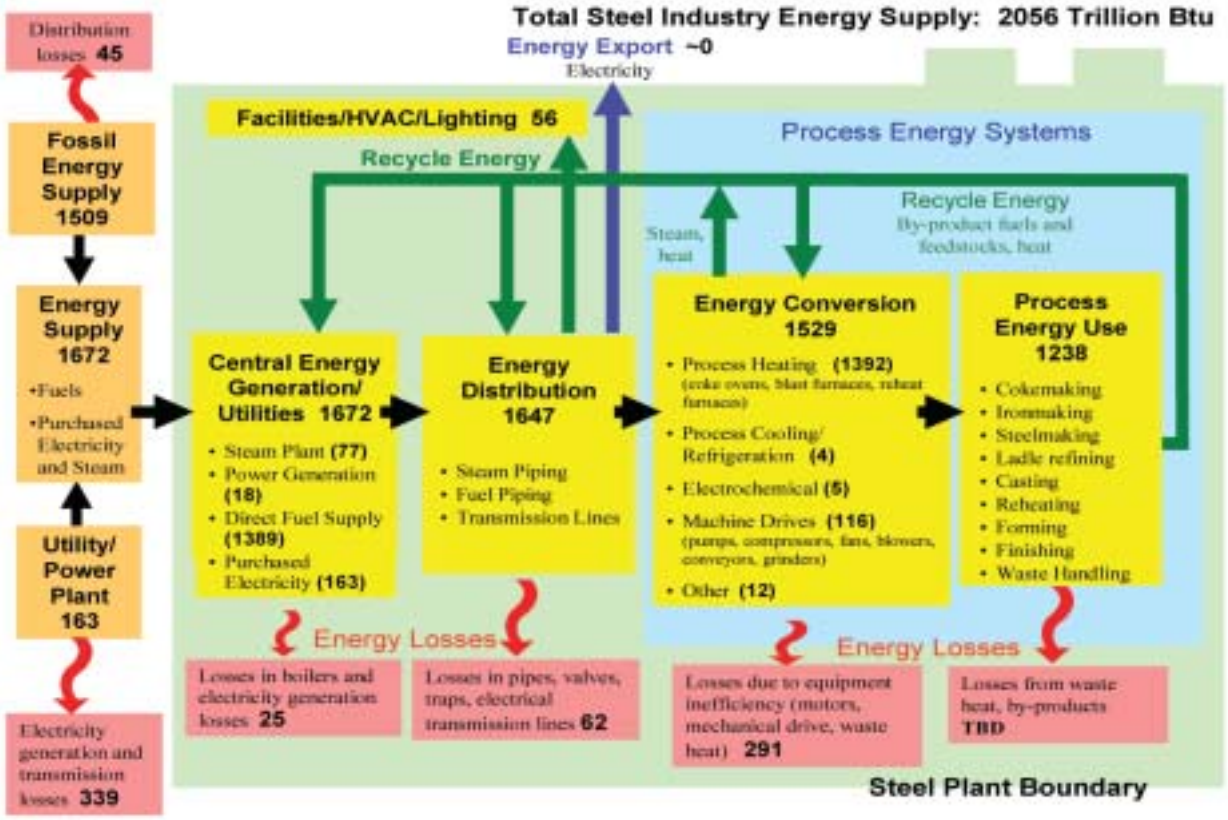


Exhibit 3
Energy Footprint for the U.S. Steel Industry



Steel Industry Shipments

In 2001, the U.S. steel industry shipped a total of 98.9 million tons of steel mill products valued at $31 billion. This represents a 9 percent drop in shipments and a 16 percent drop in revenue over similar measures for 2000. Revenues were at their lowest point since 1993. As shown in Exhibit 4, the decline in shipments on a tonnage basis between 2000 and 2001 was most severe for hot- and cold-rolled sheet, which dropped nearly 4 million tons.

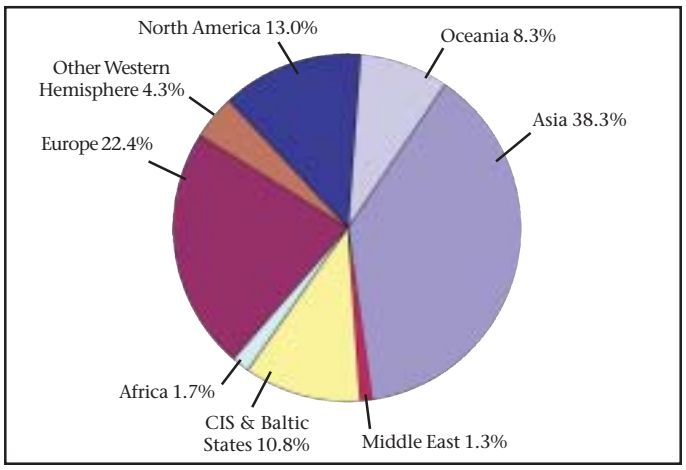
Exhibit 4
U.S. Net Shipments of Steel Mill Products
(Thousands of Net Tons)

Steel Products	2001	2000	% Change (00-01)
Sheets			
Hot-rolled	18,287	19,770	(7.5)
Cold-rolled	12,404	14,847	(16.5)
Sheets and Strip			
Galvanized hot-dipped	14,293	14,872	(3.8)
Galvanized electrolytic	3,012	3,496	(13.8)
All other metallic-coated	1,902	2,138	(11.0)
Electrical	481	529	(9.1)
Strip			
Hot-rolled	690	869	(20.6)
Cold-rolled	1,683	2,262	(25.6)
Total	**98,940**	**109,050**	**(9.3)**

World Steel Production

Total world steel production in 2001 was 931.9 million net tons. The U.S. accounted for 10.7 percent of this production, down from 12 percent in 2000. As shown in Exhibit 5, Asia is by far the largest steel-producing region, followed by Europe, North America, and the Commonwealth of Independent States (CIS).

Exhibit 5
2001 World Production of Raw Steel
(Percent of Total World Production)



THE CHALLENGE

The steel industry is one of the most energy-intensive industries in the U.S. manufacturing sector. A stable and dependable domestic source of steel is vital to America's economic and national security. However, the industry's financial and market woes in recent years have severely limited investment in research activities, emphasizing the need for public-private R&D collaboration.

Despite the domestic steel industry's modernization efforts of the past two decades, the industry has been struggling to survive. During the past 3 years, high levels of imports have caused many U.S. steel companies to declare bankruptcy (more than 30 during 2001 and 2002 alone). Because of the low profit margins and high levels of foreign competition, the industry is unable to conduct the high-risk, long-term technology R&D needed to ensure its survival in the 21st century.

The competitive and financial demands facing steel companies have made them more willing to collaborate in strategic, pre-competitive areas to improve energy efficiency in the iron and steel manufacturing processes. The industry has emphasized in the *Steel Industry Technology Roadmap* that collaborative partnerships involving government, industry, and academia will be critical to meeting the technology challenges of the future and accelerating the pace of technological innovation.

An Energy-Intensive Industry

The steel industry consumes approximately 2 quads (quadrillion, or 10^{15} Btu) of energy each year. The cost of purchasing this energy represents about 15 percent of the total manufacturing cost for steel, even higher for electric arc furnace steelmakers. The difference between the practical minimum energy requirement and actual requirements for the energy-intensive unit operations of ironmaking and steelmaking are in the range of 20 percent to 30 percent. In plain terms, the steel industry can save 20 to 30 percent of its energy costs by applying advanced technologies. The magnitude of the energy consumed by the industry makes it a prime target for energy-efficiency R&D, with potentially large energy-savings opportunities.

The Steel portfolio sponsors research on incremental improvements for energy-intensive unit operations such as ironmaking, as well as revolutionary new processes that may eliminate certain operations. Steel industry R&D is a component of the Office of Energy Efficiency and Renewable Energy (EERE) and contributes to its goals of promoting energy efficiency and productivity, thereby strengthening the country's energy security, environmental quality, and economic vitality. An analysis of current ITP steel projects estimates future savings of about 11 trillion Btu in 2010 and more than 130 trillion Btu in 2020. These estimates are in line with the recent shift to longer-term, higher-risk projects.

The Steel portfolio pursues projects in three main categories:

Knowledge Base
- Broad-based advanced metallurgy
- Enhancements to process knowledge database

Evolutionary/Incremental Improvements
- Near- to mid-term improvements to manufacturing processes
- Efficient steel process furnaces and equipment
- Process sensors and controls

Revolutionary Technologies
- Next-generation ironmaking and steelmaking technology

Strategy for Improving Steel Industry Energy Efficiency

The Industrial Technologies Program seeks to develop advanced technology for the domestic steel industry to help it survive in an environment of low profits and stiff foreign competition. A strong domestic steel industry with minimal reliance on imported raw materials and energy sources will help ensure national security.

The Industrial Technologies Program supports a portfolio of cost-shared, pre-competitive research addressing technological needs that have broad application throughout the steel industry. All research projects are selected through a competitive review process. They must address priorities outlined in the *Steel Industry Technology Roadmap* and serve the EERE mission of increasing energy efficiency.

The steel industry employs more than 150,000 people throughout the United States. The highest geographic concentration of steelmaking facilities (both integrated and scrap-based) is in the Great Lakes region, including Indiana, Illinois, Ohio, Pennsylvania, Michigan, and New York.

As a result of industry consolidation over the past several decades, the number of steelmaking facilities has decreased significantly. Large integrated mills have seen the largest decline, losing market share to imports and substitute materials, as well as facing high legacy costs. Many integrated mills have closed, and those that are still operating have reduced their workforces. The number of U.S. blast furnaces has declined from about 125 in the mid 1970s to about 40 operating furnaces today. Fewer than 20 integrated mills are currently in operation.

The Department of Energy has devised a strategy to foster both revolutionary ironmaking and steelmaking projects and incremental improvements to existing processes, thereby addressing long-term goals while meeting short-term needs. The program also strives to expand the industry's fundamental base of knowledge to optimize key processes and resource efficiency. Since 2001, the program has increased its emphasis on revolutionary steelmaking concepts in order to maximize energy savings. This shift in focus should produce dramatic drops in steelmaking energy intensity over the long-term.

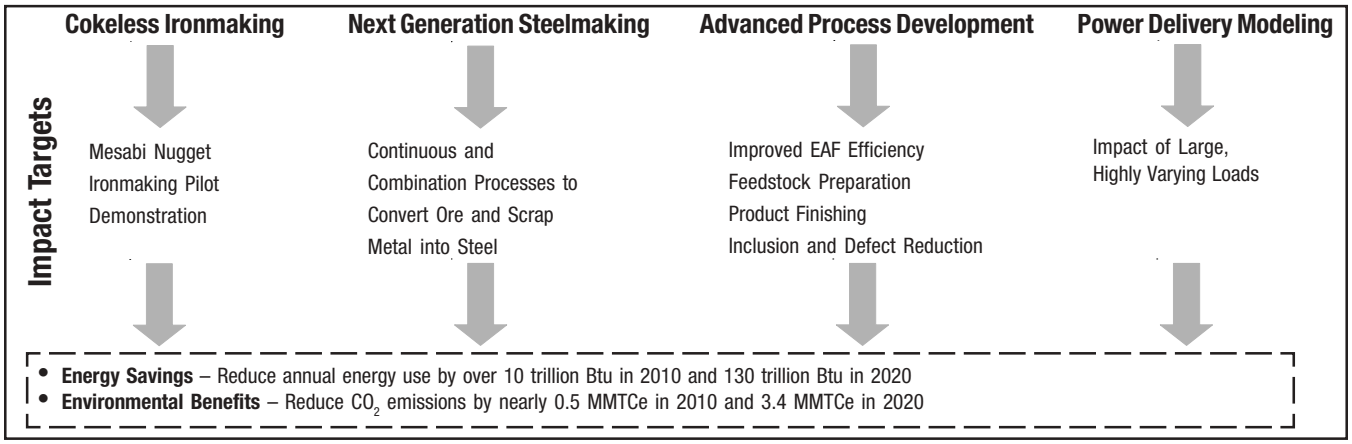
In FY 2003, the Steel portfolio was divided into four major focus areas, or pathways. These areas are:

- Cokeless Ironmaking
- Advanced Process Development
- Next Generation Steelmaking
- Power Delivery Modeling

Exhibit 6 shows the targeted technologies to be supported in each of these areas.

One of the strengths of the Steel IOF is the comprehensive participation of both industry and universities, providing both cost-sharing and in-kind support. The involvement of industry accelerates technology transfer and dissemination of research results. Industry partners represent the diversity of the steel industry and include integrated producers, mini-mill producers, suppliers, and end-users in several industries.

Exhibit 6
Steel Portfolio Pathways



FY 2003 HIGHLIGHTS & ACCOMPLISHMENTS

In fiscal year 2003, the Steel portfolio included nearly 40 projects, about half of which were completed (Exhibit 7). Ongoing projects, organized by the major process steps of ironmaking, steelmaking, casting, forming and finishing, downstream processing, and utilities/combustion, are listed in Exhibit 8. In addition, over 15 projects relevant to the steel industry funded by other EERE program activities are shown in Exhibit 9.

Exhibit 7 Steel Research Projects Completed in FY 2003

Advanced Process Development
- In-Situ, Real-Time Measurement of Melt Constituents
- Optical Sensor for Post-Combustion Control in EAF Steelmaking
- Optimization of Post Combustion in Steelmaking
- Evaluation of Sustainable Steelmaking Using Biomass and Waste Oxides
- Improving the Efficiency of Electric Arc Furnaces in the U.S.
- Enhanced Inclusion Removal from Steel in the Tundish
- MAG-GATE System for Molten Metal Flow Control
- Quantifying the Thermal Behavior of Slags
- Real-Time Melt Temperature Measurement in a Vacuum Degasser Using Optical Pyrometry
- Reducing the Variability of HSLA Steel Sheets
- Standard Methodology for Measurement of Steel Phase Transformation Kinetics Using Dilatometrics
- Validation of the Hot-Strip Mill Model
- Intermetallics for the Steel Industry
- Large-Scale Evaluation of Nickel Aluminide Rolls in a Heat-Treat Furnace at the Burns Harbor Plant
- Formability Characterization of a New Generation of High-Strength Steels for Automotive Applications
- Laser-Assisted Arc Welding
- Characterization of Fatigue and Crash Performance of a New Generation of High-Strength Steels for Autos

Exhibit 8 Active Steel Research Projects in FY 2003

Cokeless Ironmaking
- Mesabi Nugget Research Project

Next-Generation Steelmaking
- Future Steelmaking Processes
- Novel Direct Steelmaking by Combining Microwave, Electric Arc, and Exothermal Heating Technologies
- Development of a Process to Continuously Melt, Refine, and Cast High Quality Steel

Advanced Process Development
- Automated Steel Cleanliness Analysis Tool
- Pulverized Coal Injection (PCI) Combustion Behavior in the Blast Furnace During PCI at High Rates
- Clean Steels – Advancing the State of the Art
- Sustainable Steelmaking Using Biomass and Waste Oxides
- Nitrogen Removal in EAF Steelmaking by Direct Reduced Iron Fines Injection
- Recycling and Reuse of BOF/BOP Steelmaking Slags
- Ladle Metallurgy and Casting
- Hydrogen and Nitrogen Control in Ladle and Casting Operations
- Inclusion Optimization for Next Generation Steel Products
- Submerged Entry Nozzles that Resist Clogging (Plant Trials)
- Controlled Thermal-Mechanical Processing of Tubes and Pipes
- Low-NOx Heating Alternative for Round Shapes, Steel Substrate (Strip), and Coil Box Transfer Bars
- Life Improvement of Pot Hardware in Continuous Hot Dipping Processes
- Constitutive Behavior of High Strength Multiphase Sheet under High Strain Rate Deformation Conditions
- Development and Application of Steel Foam Materials and Structures
- Appropriate Resistance Spot Welding Practice for Advanced High Strength Steels
- Ultra-Low Carbon High-Strength Steels for Enhanced Stretch Formability and Dent Resistance
- Novel Low-NOx Burners for Boilers in the Steel Industry

Power Delivery Modeling
- Impact of Large, Highly Variable Loads

Exhibit 9
Examples of Other EERE Projects Relevant to the Steel Industry

Combustion Projects
- Forced Internal Recirculation (FIR) Burner

Inventions and Innovations Projects
- Clean Production of Coke from Waste Carbonaceous Fines
- Continuous Casting/Inside Rolling of Hollow Rounds
- Method of Making Steel Strapping and Strip

NICE³ Projects
- An Automatic Inspection-Based Process Advising System for Steel Products at High Temperature
- Lightweight Steel Containers
- Vanadium Carbide Coating Process

Sensors and Controls Projects
- Development of a Versatile Laser Ultrasonic System and Application to On-Line Measurement for Process Control
- Diagnostics and Control of Natural Gas-Fired Furnaces via Flame Image Analysis Using Machine Vision and Artificial Intelligence Techniques
- In-Situ, Real-Time Measurement of Melt Constituents in the Aluminum, Glass, and Steel Industries
- Thermal Imaging Control of Furnaces and Combustors (Steel & Glass)
- Tunable Diode Laser Sensors for Monitoring and Control of Harsh Combustion Environments
- Wireless Telemetry for Industrial Applications (All IOF Industries)

Small Business Innovation Research (SBIR) Grant Projects
- Fiber-Optic Sensor for Industrial Process Measurement and Control (Combustion)
- Portable Parallel Beam X-Ray Diffraction System
- Real-Time Gas Composition Analyzers for On-Line Process Control

In addition to sponsoring R&D, the Steel portfolio achieved a number of noteworthy accomplishments in 2003. These accomplishments are described below:

R&D Highlights

Mesabi Nugget Ironmaking – The Mesabi Nugget Project is a large-scale initiative to demonstrate the ITmk3 Process developed by Kobe Steel, Ltd. The ITmk3 Process is a new ironmaking technology that uses a rotary hearth furnace to turn iron ore fines and pulverized coal into iron nuggets of similar quality as blast furnace pig iron. The direct use of coal to make iron is an alternative to the current prevailing ironmaking practice that uses coke made from coal. The high-quality, low-cost nuggets can be fed into either a basic oxygen furnace or an electric arc furnace. A pilot demonstration plant in Silver Bay, Minnesota has completed its first 30 days of continuous operations as of August 2003, producing 1,000 tons of iron from Minnesota ore. The purpose of the project is to assess process conditions for producing iron nuggets that can be fed into a commercial steelmaking furnace. Participants include Mesabi Nugget LLC, Kobe Steel USA, the State of Minnesota, Cleveland Cliffs, and Steel Dynamics.

Novel Direct Steelmaking by Combining Microwave, Electric Arc, and Exothermal Heating Technologies – A novel direct steelmaking process combining multiple technologies has been evaluated by Michigan Technological University throughout 2003. Direct steelmaking eliminates the need for a separate ironmaking step, which could greatly reduce the energy intensity of the overall steelmaking process. The goal of the project is to develop a solid base of data on the process' technical, market, and economic potential and to set targets for energy use, emissions, and costs. Combinations of raw materials are being tested with different heating methods to determine the effect on steel yield, carbon content, and exhaust gas emissions.

Future Steelmaking Processes – Carnegie Mellon University and U.S. Steel are examining the feasibility of using a combination of proven technologies to produce iron more efficiently and with lower capital and operating costs. The goal is to develop a flexible fossil fuel-based process as an alternative to energy- and emissions-intensive coke-based blast furnace ironmaking. The project team is creating energy and materials balance models for a number of existing smelting technologies combined with rotary hearth furnace technology. The models will be used to perform process optimization and economic calculations.

Enhancing the Operation of Highly Varying Industry Loads to Increase Electricity Reliability, Quality, and Economics – The random nature and size of the electric loads associated with the operation of electric arc furnaces, rolling mills, and large motors can cause large frequency deviations on the electricity grid. NiSource Energy Technologies and ITP are investigating a novel concept for handling highly varying loads while enhancing electric power reliability and quality. The concept comprises a number of load forecasting and coordination techniques that can be applied in a particular utility control area. In FY 2003, NiSource ran simulations and directly integrated some of the techniques with steel mill operators. The results of this project will have application well beyond the steel industry and should yield economic and operational benefits.

Laser-Based Ultrasonic (LUT) Tube Wall Thickness Gauge – In March 2002, the first LUT tube wall thickness measurement system was installed at the Timken Company's #4 mill and has been operating successfully ever since. This system displaces a slow, statistical-based methodology with an advanced real-time system that performs a quality characterization of every tube produced, not just a sampling. As of March 2003, the system had inspected 388,000 tubes, representing an instrument "up time" of 90 percent. Energy savings are estimated to be 23 billion Btus and cost savings were over half a million dollars, largely as a result of record low levels of scrap at the mill. The R&D project that resulted in this commercial success was sponsored by the ITP Sensors & Automation portfolio.

Controlled Thermal-Mechanical Processing (CTMP) of Tubes and Pipes – This successful project has yielded a technology for generating targeted microstructures in the manufacture of tubes and pipes. The technology consists of an integrated control model that combines the results of metallurgical fundamental studies, models of the thermal and deformation processes, and product performance response relationships. One of the industrial research partners, The Timken Company, has installed the technology and expects annual savings of 70 million cubic feet of natural gas through reduced heat treating requirements. Timken is continuing to work collaboratively with Oak Ridge and Sandia National Laboratories and the Colorado School of Mines on additional models.

Molten Metal Flow Control System – Precise control of the flow of molten steel at 3000 degrees Fahrenheit is very difficult, but is critical for quality control in casting. In February 2003, the Concept Engineering Group, Inc. conducted the first full-scale, hot metal test of an electromagnetic valve that it designed and built to control the flow of molten metal. This successful test of the system is a critical step in transferring the technology to the steel industry. The new technology yields precise control of molten steel in continuous casting, resulting in less turbulence, oxidation, and impurity entrapment. Energy savings of 2 trillion Btus per year industry-wide, as well as quality and productivity benefits, are anticipated.

Nickel Aluminide Transfer Rolls – Bethlehem Steel has installed a set of 101 transfer rolls in its slab plate mill in Burns Harbor, Indiana. Bethlehem worked with Oak Ridge National Laboratory on the development of these rolls, which are made of an advanced intermetallic alloy with superior performance in high-temperature applications such as steel reheating and heat treating furnaces. The rolls at the Burns Harbor mill replace conventional steel rolls that bulged and blistered, necessitating frequent unscheduled maintenance shutdowns. The blisters also caused surface defects on the steel being processed, increasing the amount of steel that had to be reworked. The new rolls have reduced the number of shutdowns and improved product quality, leading to significant cost and energy savings.

Improving the Efficiency of Electric Arc Furnaces – Faced with high electricity rates in the California market, Tamco Steel was the first site of an effort to reduce electric energy use in domestic electric arc furnaces steelmaking. In an effort jointly supported with Steel Manufacturers Association members, DOE sponsored development of a Steelmaker Pilot, an intelligent process control system that integrates advanced, knowledge-based computing with the more traditional algebraic approaches used in steelmaking. Based on data collected and new practices, it is now possible for Tamco to produce a ton of molten steel with less than 400 KWH.

Improving Refractory Service Life and Recycling Materials in EAF Steel Production – Oregon Steel has used a new slag foam chemistry model to increase the service life of its electric arc furnace sidewalls to 1200 heats, a 20 percent improvement. The model was developed by the Albany Research Center and supported by the Industrial Technologies Program as part of a project to improve refractory service life by maintaining better control of slag chemistry and the slag foaming process. Oregon Steel is also evaluating an automated

slag foam control model. Improved control of the slag foaming process has the added benefit of increasing the energy efficiency of the furnace and reducing its pollutant emissions.

Optimization of Post Combustion in Steelmaking – With ITP support, Carnegie Mellon University has developed a three-dimensional computational fluid dynamic model to optimize post-combustion control in steelmaking. During both BOF and EAF steelmaking, a significant amount of carbon monoxide is generated; post combustion of this carbon monoxide releases heat energy above the molten steel bath. Efficient control and transfer of this heat energy can reduce energy costs and increase productivity by decreasing furnace melt times. The potential annual savings in both BOF and EAF steelmaking are estimated to be $50-$100 million dollars.

Hot-Strip Mill Model – The Integ Process Group, Inc. has released its hot-strip mill model, a software model that simulates steel being processed in a hot-strip mill and predicts its final mechanical properties. Several steel companies, including U.S. Steel, have used the model to study their hot-strip processes, in which 10-inch thick steel slabs are reduced to a quarter-inch or less. DOE and the American Iron and Steel Institute jointly sponsored the development of this software model.

Pot Hardware Life for Galvanizing Lines – Major progress has been made in developing materials to increase the life of molten zinc pot hardware on steel galvanizing lines by a factor of ten. Interest in this project is high because these high-speed hot-dip lines often experience catastrophic component failures requiring shutdown of the line. Steel industry hot-dip operators are collaborating with researchers from West Virginia University, the Lead Zinc Research Organization Inc., and Oak Ridge National Laboratory.

Continuous Process for Melting, Refining, and Casting Steel – The University of Missouri-Rolla has been awarded a contract for converting preheated steel scrap into high-quality steel under the Steel Industry Research Challenge solicitation. Rolla, in collaboration with Techint Technologies and several steelmakers, will develop a continuous process to melt, refine, and cast steel.

Partnership Highlights

Student Fellowship Program – The Steel Manufacturers Association (SMA), in concert with steel companies and the DOE/EERE, has established a cooperative education program for selected college students. Students are selected on the basis of knowledge, experience, desire, and initiative. The sponsoring company submits details for a potential student project. At the conclusion of the work effort, SMA-DOE Fellows and industry mentors provide a joint critique for the purpose of determining the success of the study program and the students' interest in the steel industry. Fourteen students participated in this program in FY 2003.

Improving Energy Efficiency Today

Technology Delivery – EERE/ITP's Technology Delivery activities offer products and services to assist industry in saving energy in the near-term. These products and services include software tools and associated training to improve the efficiency of plant utility systems, cost-shared plant assessments, no-cost plant audits for small- and mid-size companies, and numerous helpful publications describing applications of good plant operating practices. Activities such as these have the potential to save the steel industry millions of dollars annually. To learn more, please visit http://www.oit.doe.gov/bestpractices/; for more information on the no-cost audits, visit http://www.oit.doe.gov/iac.

Plant-wide Assessments (PWAs) – PWAs are cost-shared assessments of plant utility and process-related energy efficiency opportunities across a plant. Plants are selected through a competitive solicitation. In FY 2003, assessments took place at two Round IV PWA winners – Charter Steel of Wilton, Iowa and North Star Steel of Saukville, Wisconsin. In addition, Fawbrook Steel was selected in the Round V solicitation in early FY 2003.

The final PWA report from North Star Steel was received in the spring of 2003. In order to replicate the benefits at similar plants, the report will be sent to the general managers and environmental managers at North Star's six other plants. A summary report will also be made available through the Steel Manufacturer's Association (SMA) for member use. In June, the North Star plant manager discussed the DOE assessment and results as the lead speaker at the Cargill (parent company of North Star Steel) quarterly meeting. Based on the experience of other manufacturers, each steel mill performing a PWA can expect to cut energy costs by anywhere from $1 million to $10 million per year.

Disseminating Research Results to Industry

Technical Papers and Articles – The Industrial Technologies Program presented a paper at two key steel industry conferences in early FY 2003:

- *Department of Energy, Office of Industrial Technologies R&D* presented at the AISE 2002 Annual Convention and Steel Expo in October 2002
- *Industry Government on Research to Improve the Energy Efficiency and Productivity of EAF Steelmaking* presented at the 60th Electric Furnace Conference in November 2002

ITP Web Site – The ITP Web site is a valuable tool for disseminating information on the program's activities. The Web site highlights steel industry R&D projects, provides access to EERE publications, and notes upcoming solicitations. The Web site also contains a "News" section that provides articles on recent events, updates on research successes, and notification about new software tools and other services of potential interest to the steel industry.

Steel Newsletter – Throughout FY 2003, ITP distributed a monthly electronic newsletter to more than 700 steel industry personnel and other stakeholders in DOE research aimed at the steel industry. Entitled *Steel Industry News from the Industrial Technologies Program at DOE*, the newsletter highlights recent accomplishments and milestones of Steel R&D projects.

Steel Industry of the Future CD-ROM – In March 2003, EERE/ITP released a CD-ROM subtitled "Resources and Tools for Energy Efficiency and Cost Reduction Now." The CD is designed to assist steel industry plant managers and engineers in quickly finding information on technical R&D results, technical assistance, training, and other products and services that ITP can provide to the steel industry.

Energy Analysis – Targeting Energy Efficiency

Energy Bandwidth Study – An energy "bandwidth" showing the magnitude of energy savings possible for each major steelmaking process was created using data from the Fruehan and Stubbles studies completed in earlier years. The results indicated that advanced steelmaking processes that eliminate coke and use less raw materials, electricity, and other fuels can yield energy savings of 18 percent, about 3 million Btu/ton of steel. The bandwidth is being used to provide a rationale for supporting R&D on revolutionary new technologies with the highest potential impact on industry energy consumption.

Energy Footprint Study – In FY 2003, ITP developed an energy footprint study of the U.S. steel industry. The footprints – one for the integrated steelmaking sector and one for the electric arc furnace-based sector – show the total flow of energy throughout the industry. The energy flow and losses are shown for energy supply, central energy generation/utilities, energy distribution, energy conversion, and process energy use. Under the energy conversion and process energy use categories, the footprint breaks down the energy use for each process step. Use and losses are shown for each process heating operation and for the various motor-driven systems. The goal of this study is to provide a baseline of energy consumption and loss data for each major operation in the steel industry. The magnitude of the energy losses can provide guidance to the program on areas of R&D opportunity.

Climate VISION

On February 14, 2002, President Bush announced a new strategy to address the long-term challenge of global climate change. The President committed to reducing America's greenhouse gas intensity – the ratio of emissions to economic output – by 18 percent in the next decade, and challenged American businesses and industries to undertake broader efforts to help meet the goal. The President's strategy, known as Climate VISION (Voluntary Innovative Sector Initiative: Opportunities Now), is focused on voluntary partnerships between the government and entire industry sectors. These partnerships aim to reduce the projected growth in America's greenhouse gas emissions through research, development, and deployment of energy-saving technologies and process.

The U.S. Department of Energy, along with other key federal agencies, recognizes that major, energy-intensive sectors of the American economy are undertaking significant initiatives to meet the President's challenge. These initiatives build upon the progress made by the industrial sector in the past decade: from 1990-2001. During this time, the economy grew by almost 40 percent, while greenhouse gas emissions in the industrial sector remained constant. The Industrial Technologies Program (ITP) is working in partnership with the U.S. steel industry through the American Iron and Steel Institute (AISI) to implement activities in support of AISI achieving its Climate VISION commitment. A Climate VISION workplan is being developed where AISI will be collaborating with the federal government on near-term energy efficiency activities, cross-sector projects, and R&D to develop and commercialize advanced technology (see Climate VISION Web site www.climatevision.gov/).

TOOLS, PUBLICATIONS, AND RESOURCES AVAILABLE

EERE offers valuable tools and publications to help steel companies improve productivity and energy efficiency. Some of these resources are described below. See the Web site at http://www.oit.doe.gov/steel for a complete listing.

Steel Industry Technology Roadmap – The *Steel Industry Technology Roadmap* represents an industry-defined, long-term agenda of research and development. As a public document, the roadmap provides a clear indication to both government and the private sector of the desired directions to be followed in future steel-related research. The roadmap was updated in FY 2002 in response to technological advances, changes in the global market, and new technical insights. To learn more, please visit http://www.oit.doe.gov/steel/visions.shtml.

Fact Sheets and Success Stories – Publications describing ongoing R&D projects, emerging technologies, and commercial successes are available on the Web site at http://www.oit.doe.gov/factsheets/fact_st.shtml-steel.

Resources and Tools for Energy Efficiency and Cost Reduction Now CD – This CD provides tips and tools for spotting the biggest energy-saving opportunities in steel mills today as well as details on energy-efficiency technologies. For a copy of this CD, please send an email to clearinghouse@ee.doe.gov.

Cost Reduction Now Brochures – A series of brochures on motors, steam systems, compressed air systems, pump systems, process heating, and other topics can help companies recognize low-cost and quick-payback energy-saving opportunities. To learn more, please visit http://www.oit.doe.gov/steel/tools.shtml.

Energy and Environmental Profile of the U.S. Iron and Steel Industry – The profile, part of an industry series, benchmarks the energy and environmental characteristics of major unit operations in the steel industry. To learn more, please visit http://www.oit.doe.gov/steel/profile.shtml.

Theoretical Minimum Energies to Produce Steel for Selected Conditions – A DOE-sponsored study has determined the theoretical minimum energy requirements for producing steel from ore, scrap, and direct reduced iron. Dr. Richard Fruehan's report, *Theoretical Minimum Energies to Produce Steel for Selected Conditions*, provides insight into the potential energy savings (and associated reductions in carbon dioxide emissions) for ironmaking, steelmaking, and rolling processes. To view the report, please visit http://www.oit.doe.gov/steel/pdfs/theoretical_minimum_energies.pdf.

Energy Use in the U.S. Steel Industry: A Historical Perspective and Future Opportunities – Renowned industry expert Dr. John Stubbles has projected the energy savings that the U.S. steel industry could reasonably expect to achieve over the next 10 years. The report examines the potential impacts of state-of-the-art technologies and operating practices, as well as structural changes in the industry itself. To view the report, please visit http://www.oit.doe.gov/steel/pdfs/theoretical_minimum_energies.pdf.

Ironmaking Process Alternatives Screening Study – This study evaluates and compares a number of alternative ironmaking processes, some already proven and some under development, that will feed iron units to current and future steelmaking processes. To view the report, please visit http://www.oit.doe.gov/steel/pdfs/ironmaking_process.pdf.

HOW TO GET INVOLVED AND CONTACT INFORMATION

Partnership Information

Public-private partnerships are the foundation of ITP's technology delivery strategy. ITP includes its partners in every phase of the technology development process to focus scarce resources where they can have the greatest impact on industrial energy efficiency. To learn more, please visit our Web site at www.eere.energy.gov/industry.

- Collaborative, **cost-shared research and development** projects are a central part of ITP's strategy. Annual solicitations provide technology development opportunities in a variety of energy-intensive industries.

- **Industries of the Future Partnerships** increase energy efficiency in the most energy-intensive industries. In addition to cost-shared research and development projects, industry partners participate in the development of vision and roadmap documents that define long-term goals, technology challenges, and research priorities.

- **Allied Partnerships** provide an opportunity for ITP to reach a broad audience of potential customers by allying with corporations, trade associations, equipment manufacturers, utilities, and other stakeholders to distribute industrial energy efficiency products and services. By becoming an Allied Partner, an organization can increase its value to clients by helping them achieve plant efficiencies.

- **State energy organizations** work with ITP in applying technology to assist their local industries. ITP assists states in developing IOF partnerships to mobilize local industries and other stakeholders to improve energy efficiency through best practices, energy assessments, and collaborative research and development.

- **EERE's technical programs** (of which ITP is one of eleven) give manufacturers access to a diverse portfolio of energy efficiency and renewable energy technologies and bring advanced manufacturing technology to the renewable energy community. For more information, access the EERE home page at www.eere.energy.gov.

- The President's **Climate VISION** (Voluntary Innovative Sector Initiatives: Opportunities Now) effort also offers opportunities for manufacturers to pursue cost-effective actions that will reduce greenhouse gas emissions. See www.climatevision.gov for details.

Access to Resources and Expertise

The Industrial Technologies Program provides manufacturers with a wide variety of industrial energy efficiency resources to help your company cut energy use right away. Visit our site at www.eere.energy.gov/industry or call the EERE Information Center at 877-337-3463 to access these resources and for more information.

- ITP offers **energy management best practices** to improve energy efficiency throughout plant operations. Improvements to industrial systems such as compressed air, motors, process heat, and steam can yield enormous savings with little or no capital investment.

- Our suite of powerful system optimization **software tools** can help plants identify and analyze energy-saving opportunities in a variety of systems.

- **Training sessions** are held several times per year at sites across the country for companies interested in implementing energy-saving projects in their facilities. DOE software tools are used as part of the training sessions.

- ITP's qualified **industrial energy specialists** will work with your plant personnel to identify savings opportunities and train staff in the use of ITP software tools.

- Our extensive library of **publications** gives companies the resources they need to achieve immediate energy savings.

- **Plant-wide energy assessments** are available to manufacturers of all sizes interested in cutting their energy use. Cost-shared solicitations are available each year for plant-wide energy assessments. In addition, no-cost, targeted assessments are provided to eligible facilities by teams of engineering faculty and students from 26 university-based Industrial Assessment Centers around the country.

- The **DOE Regional Offices** provide a nation-wide network of capabilities for implementing ITP's technology delivery strategy. Regional Offices are located in Atlanta, Boston, Chicago, Denver, Philadelphia, and Seattle. Visit www.eere.energy.gov/rso.html for more information.

Where to Go to Get More Information

Visit our Web site - http://www.oit.doe.gov/steel

Learn about all EERE Programs - http://www.eren.doe.gov

Ask an Expert - The Industrial Technologies Clearinghouse is a great way to access ITP's resources. Times available are 9 a.m. to 8 p.m. EST (6a.m. to 5 p.m. PST).
Phone: 1-800-862-2086 Fax: 360-956-2214 Email: clearinghouse@ee.doe.gov

For print copies of DOE, EERE, and ITP Publications, contact -
Energy Efficiency and Renewable Energy Clearinghouse (EREC)
P.O. Box 3048
Merrifield, VA 22116
Phone: 800-363-3732 Fax: 703-893-0400 Email: doe.erec@nciinc.com

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A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and great energy independence for America. By investing in technology breakthroughs today, our nation can look forward to a more resilient economy and secure future.

Far-reaching technology changes will be essential to America's energy future. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a portfolio of energy technologies that will:

- Conserve energy in the residential, commercial, industrial, government, and transportation sectors
- Increase and diversify energy supply, with a focus on renewable domestic sources
- Upgrade our national energy infrastructure
- Facilitate the emergence of hydrogen technologies as a vital new "energy carrier"

The Opportunities

Biomass Program
Using domestic, plant-derived resources to meet our fuel, power, and chemical needs

Building Technologies Program
Homes, schools, and businesses that use less energy, cost less to operate, and ultimately, generate as much power as they use

Distributed Energy & Electric Reliability Program
A more reliable energy infrastructure and reduced need for new power plants

Federal Energy Management Program
Leading by example, saving energy and taxpayer dollars in federal facilities

FreedomCAR & Vehicle Technologies Program
Less dependence on foreign oil, and eventual transition to an emissions-free, petroleum-free vehicle

Geothermal Technologies Program
Tapping the Earth's energy to meet our heat and power needs

Hydrogen, Fuel Cells & Infrastructure Technologies Program
Paving the way toward a hydrogen economy and net-zero carbon energy future

Industrial Technologies Program
Boosting the productivity and competitiveness of U.S. industry through improvements in energy and environmental performance

Solar Energy Technology Program
Utilizing the sun's natural energy to generate electricity and provide water and space heating

Weatherization & Intergovernmental Program
Accelerating the use of today's best energy-efficient and renewable technologies in homes, communities, and business

Wind & Hydropower Technologies Program
Harnessing America's abundant natural resources for clean power generation

To learn more, visit www.eere.energy.gov

Steel Industry of the Future

Industrial Technologies Program
Boosting the productivity and competitiveness of U.S. industry

U.S. Department of Energy
Energy Efficiency and Renewable Energy

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